Available online at www.sciencedirect.com

SciVerse ScienceDirect

ELSEVIER

Procedia - Social and Behavioral Sciences 48 (2012) 796 – 805

Procedia
Social and Behavioral Sciences

Transport Research Arena– Europe 2012

Accurate Localisation Based on GNSS and Propagation Knowledge for Safe Applications in Guided Transport

Juliette Marais[a,b,*], Sébastien Ambellouis[a,b], Amaury Flancquart[a,b], Sébastien Lefebvre[a,b], Cyril Meurie[c], Yassine Ruichek[c]

[a]*IFSTTAR, LEOST, F-59650 Villeneuve d'Ascq, France*
[b]*Univ Lille Nord de France, F-59000 Lille*
[c] *Université de Technologie de Belfort-Montbeliard, Systems and Transportation Laboratory, F-90010 Belfort, France*

Abstract

Global Navigation Satellite Systems (GNSS) are widely spread (with Global Positioning System - GPS) in intelligent transport systems and offer a low cost, continuous and global solution for positioning. Unfortunately, urban users are often the most demanding of accurate localisation but receive a degraded service because of signal propagation conditions. Several mitigation solutions can be developed. We propose, within the CAPLOC project (2010-2013) to deal with inaccuracy by associating image processing techniques for a 3D reconstruction of the surrounding environment and the signal propagation knowledge.

Keywords: Localisation; Satellite; Image processing; Accuracy.

1. Introduction

1.1. Context

The policy on transportation system enhancement has recently benefited from decisions, at the European or national level with, for example, in France « Grenelle de l'Environnement ». This drives to the definition of concrete objectives in order to limit car uses and to make urban public transport more attractive and efficient.

* Corresponding author. Tel.: +33-320-438-495; fax: +33-320-438-359
E-mail address: juliette.marais@ifsttar.fr.

doi:10.1016/j.sbspro.2012.06.1057

In the close future, the positioning information of any actor in a transportation system will have a growing importance. This information will allow the operator to enhance its system capacity and to provide contextual information to the passengers, to the drivers or to the maintenance workers.

A large panel of applications relies on positioning information: navigation, of course, but also eco-driving, toll, « pay as you drive » insurance, parking management, speed limitation, traffic signal pre-emption…

The use of positioning data can be seen as a common or transversal service. Indeed, in an intermodal transportation system, each actor waits for the correct information at the right time but can also be an actor of the system by broadcasting information for community as probe vehicles do.

The position is a synchronizing element of the information system. Services like traffic management will be enhanced and will allow more flexibility. The system will be more reliable as it benefits from a context enriched by the position. New services relying on « Context Aware » or « Ubiquitous Computing » will be deployed with more efficiency.

This highlights the importance of localisation transportation systems in Intelligent Transport Systems, including automotive vehicles and urban transport, even guided ones.

The objective of the CAPLOC project is to succeed in delivering accurate positioning information, available everywhere in a global context of cost reduction.

The positioning system offering the best compromise cost/simplicity/performance is today undoubtedly the satellite-based radio navigation system GPS (Global Positioning System). Moreover, in Europe, it can be enhanced by using the EGNOS (European Geostationary Navigation Overlay System) signals, to obtain a better accuracy.

These solutions correspond also well to the actual demands of fleet operators (including guided transport). These are expressing the strong need to reduce the dependence on the infrastructure, because of the augmentation of vandalism acts and because of the growing maintenance costs.

Unfortunately, if the urban user of GPS is the most demanding in terms of accuracy, he has to face to a degraded service. Indeed, the signal propagation conditions are strongly dependent on the density of the obstacles that degrades the optimal reachable performances. In particular, EGNOS, being composed of geostationary satellites is received poorly in urban canyons (Kovar 05).

In this context, the main objective of CAPLOC is to provide an innovative tool for the positioning function, relying on satellite-based technologies, GPS and EGNOS, and mitigating the difficulties linked to the constricted environment of reception. This tool has to be usable for every transport modes, and aims at becoming a key function of a large panel of mobile applications.

1.2. Satellite-based localisation in urban environments

Global Navigation Satellite Systems (GNSS) have penetrated the transport market through applications such as monitoring of containers or fleet management. These applications do not necessarily request high availability, integrity and accuracy of the positioning system. However new applications dealing with liability issues (toll, insurance…) as well as safety-related applications (automatic guidance or control) will require more stringent performances. The American GPS is the only fully global operational solution for the moment and this monopole reduces the possibilities of measurement redundancy and diversity and, thus, limits the reachable performances. Since October 2009, the European Satellite-Based Augmentation System (SBAS) EGNOS enhances accuracy of the positioning. Indeed, a receiver able to use both EGNOS and GPS signals benefits from the ionospheric corrections as well as parameters for protection levels computation.

Unfortunately, main transport applications are used in dense urban environments, highly constraining for the signal propagation. The reception conditions are bad and often impact each available satellite signal, in particular the EGNOS satellites, because of their geostationary nature. As GNSS positioning relies on the propagation time measurement of at least 4 satellites simultaneously, the consequences of environmental obstructions are unavailability of the service, but also multipath reception that degrades in particular accuracy of the positioning. Indeed, Non Line Of Sight (NLOS) signals – i.e. signals received after reflections on the surrounding obstacles with no direct ray – frequently occur in densely built environments and degrade localisation accuracy because of the delays observed on the propagation time measurement that create an additional error on the pseudorange estimation.

Literature focusing on techniques for localisation performance enhancement in constricted environments is abundant. The most spread rely on multi-sensor-based approaches, for which the goals are to compensate the lack of performance of GNSS by adding other sensors (odometer, Inertial Measurement Unit, etc), that increases the system complexity. Accuracy is often enhanced by mitigating multipath error (Lentmaier 08). Such techniques can propose exclusion procedures to avoid using corrupted data (Pervan 96). Pseudorange reliability can be qualified by the SNR (Signal to Noise Ratio) or the elevation angle (Wang 07). We will explore the use of images to determine the state of reception of every satellites. However, we know that, in constricted environment, satellite visibility is often weak and to exclude satellites in the position estimation process can create more positioning errors (non coherent positions) or large unavailability periods.

2. The CAPLOC concept

2.1. Principle

In the CAPLOC project, we propose to enhance localisation performances in particular accuracy, by knowing the structure of the environment crossed by the vehicle. This structure can be obtained by images provided by several cameras installed on the roof of the vehicle. This concept has already been patterned by INRETS (now IFSTTAR) in 2006 (France) and 2008 (international) (Marais 08). Figure 1 is an illustration of two kinds of representations of the masking obstacles around the antenna. The left view is a polar view. The white area is the sky, the blue one the masking zone. The right view is another presentation of the same masking area drawing the elevation angle of the mask versus the azimuth.

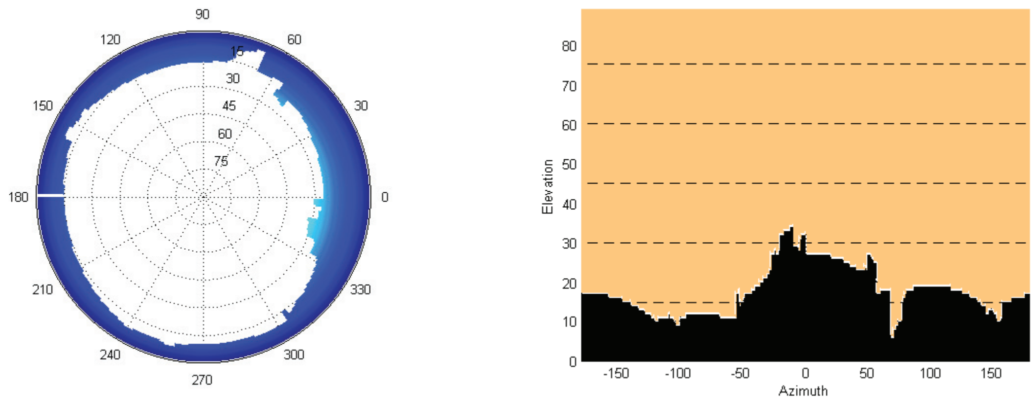

Fig. 1. Masking obstacles around the receiver antenna (left: skyview, right: panoramic view). These data have been obtained using the SE-NAV software (www.oktal-se.com/se-nav).

In a first step, the state of reception of satellite signals is determined by comparing satellite positions and obstacle positions around the antenna. Satellites positioned in the sky area are directly visible (LOS – Line Of Sight), satellites positioned behind the mask are NLOS.

In (Meguro 08), the authors explore this way by calculating the visible sky area with an infrared camera. The most interesting obstacles are the bulkiest ones (buildings for example). The thinnest ones create local phenomena that will stay very shortly if the receiver moves and will not present major problems in our dynamic applications. For the detection and the characterization of these obstacles, we are developing an application based on color and texture characteristics of the image in order to extract as much information as possible. The information extracted from the image will allow us to detect, then to exclude, the satellites that degrade the receiver performances, as the RAIM (Receiver Autonomous Integrity Monitoring) algorithm often does in aviation applications. However, these exclusion policies will often reduce drastically availability in urban environments.

In a second step, we will develop a process of 3D model creation in order to model ourselves the environment structure around the antenna. This process has to be easy to use and compatible with the operational constraints of the transport operators. The goal is to obtain a 3D model with, if possible, only one run and the shortest mobilization of the vehicle. This model, associated to a ray tracing tool (Godefroy 06, Suh 07), will allow us to calculate, then correct, the pseudorange error induced by the signal reflections.

The approach has already been validated with the PREDISSAT tool (Marais 05). PREDISSAT is, however, not a real time process and can largely benefit from new image processing improvements.

2.2. Image processing

Regarding vision and image processing, the objective is to characterize, in real time, the environment of reception of GNSS signals. Then, two research axes are identified:

First, visible sky detection by an automatic process of segmentation and classification of color images. The technological challenge is to develop a system based on cameras with large field of view (180°) able, first, to identify in an image the regions corresponding to the « sky » and the regions of « non sky » and, second, to characterize the different entities of the image based on their textures (building facades, roof, vegetation, etc).

Second, 3D modeling of the environment. The technical objective is to develop a vision system able to build in three dimensions the environment around the GNSS antenna on the basis of multiple views. The first step aims at defining a set of 3D points in a way as dense and accurate as possible. Two main methods are considered to compute the depth information: one uses images taken successively (*Structure from Motion*), the other uses images taken at the same time but from slightly differing viewpoints (*Stereovision*). In this project, the stereovision approach is chosen to compute 3D points. The second step is to determine a mesh from the 3D points previously computed. The better the quality of this mesh, the more efficient the pseudorange correction stage. This will be studied in this project.

2.3. Satellite-based localisation algorithms

Satellite-based localisation relies on the use of 4 satellite signals simultaneously received. The reception of these signals is degraded by the propagation conditions in the environment close to the receiver antenna. We are concerned by the following approaches:

Failure detection before the calculation of the position in order to exclude the corresponding data. The reflected signals will be identified thanks to the environment description provided by the vision system. This technique will be close to RAIM algorithms or to the work of (Meguro 08).

In a second step, more ambitious, we aim at correcting the error caused by these reflections. It supposes that the 3D model will be accurate enough so that the deterministic estimation of the signal delay can be pertinent.

3. First results with experimental data

The project started in October 2010. The 3D model and the error corrections are long term work and results are hoped at the end of the project. In this paper, we present objectives and results of the project, at T+1 year.

The last section of this paper will describe some of the results obtained with new image processing algorithms and an illustration of their use with an exclusion policy.

3.1. Image processing

In this section, a new image processing strategy to detect visible sky in the image is presented. After satellite repositioning, it is possible to estimate the number of satellites located in a sky region (satellite with a direct signal) and in a non-sky region (satellite with a blocked/reflected signal). For that, we use a laboratory vehicle which is equipped with a GPS-RTK (Real Time Kinematic) and a fisheye camera characterized by a wide field of view (180°) located on the roof and oriented upwards to capture images of the sky.

Many segmentation methods exist in the literature, but most of them do not permit to obtain satisfactory results with a real time constraint. In previous works (Meurie 10) and (Cohen 10), a color and texture based segmentation technique, providing good results, has been proposed. By combining this technique and a k-means based classification step, we obtain a classification rate of 97.4%. Nevertheless, the processing time is very high considering our targeted real time application. In this context, a new strategy is presented in this paper. We propose a three steps strategy as presented in the figure 2.

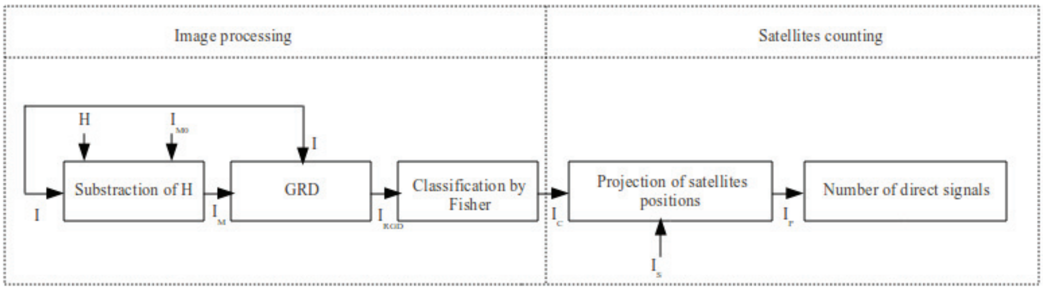

Fig. 2. Synopsis of the overall process

The first step consists in simplifying the acquired image using a geodesic reconstruction by dilatation (GRD) with an optimum parameter of contrast (H=75). In figure 2, I and H are respectively the acquired image and the contrast parameter which indicates the level of peaks to delete. Let I_{M0} be the mask of the used lens. In the geodesic reconstruction, the color image I_M is obtained by subtracting the parameter H to the color components of the initial image I (i.e. $I^{Ci} – H*I_d$ where I^{Ci} represents a color component, and I_d

is the identity matrix). The result of the geodesic reconstruction by dilatation is denoted I_{GRD}. The choice of the geodesic operator is explained by its effect on the sky grayscale distribution. Indeed, as one can notice, the image acquisition is done in different conditions (illumination variation, lack of stability of the camera due to the movement of the vehicle, etc). For this reason, it is useful to homogenize the sky region by a geodesic reconstruction by a dilatation step.

The second step concerns the classification of the pixels into two classes (sky and non-sky) with the Fisher algorithm. In previous works (Attia 11), the authors have compared the performance of different clustering algorithms. The Fisher algorithm has given the best results with the lower computational time (1s/image). Figure 3 illustrates the classification results according to the components of the used color space. One can notice that the blue component gives the best results with a good classification rate of 95.5%.

The third step concerns the counting of satellites with direct/blocked/reflected signals. For that, satellites are projected in the acquired and segmented images. Then, it is easier to identify the number of satellites located in a sky region of the classified image (resp. in a non-sky region) in order to count the number of satellites with direct signal (resp. with blocked/reflected signals). Figure 4 illustrates the results of the proposed strategy for two images (among 170 images) of the database. In this figure, the satellites with a direct signal (resp. blocked or reflected) are colorized in green (resp. in red or blue).

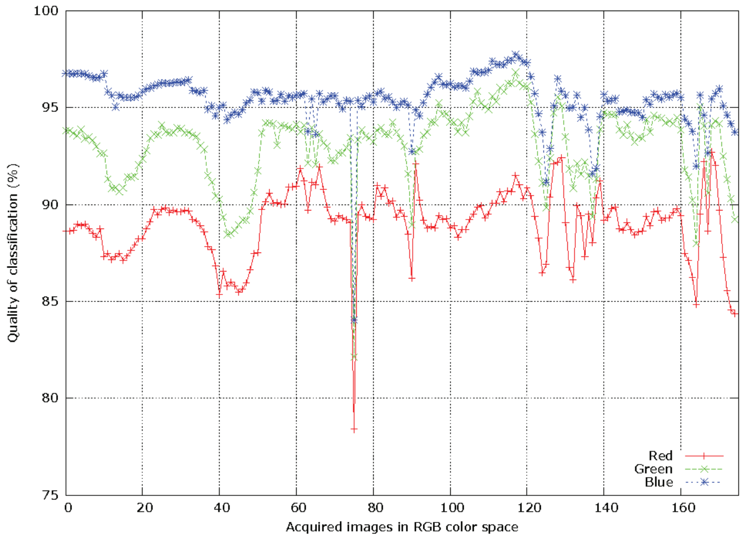

Fig. 3. Evaluation of the sky/non-sky classification (with the Fisher algorithm)

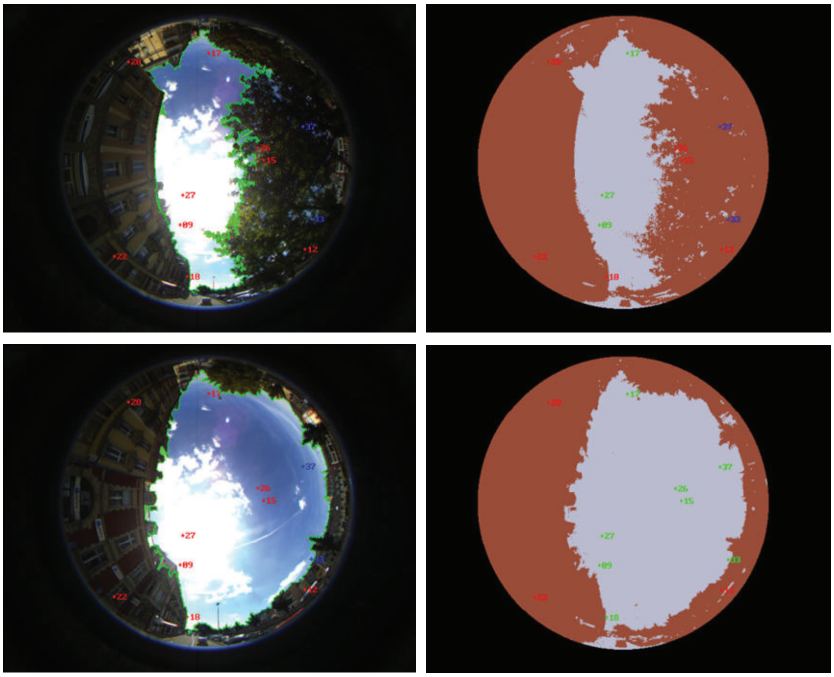

Fig. 4. Results of the image processing (left to right: acquired image with the projection of the satellites and the calculated horizon line, the classified image into two classes (sky and non-sky) with satellites projection)

3.2. Localisation

The first use of the satellite state determination is the ability to exclude the NLOS satellites. Indeed, due to the delay caused by the reflected signals, the NLOS signals induce inaccuracy in the positioning.

An algorithm excluding NLOS satellites has been implemented in the CityVIP project and has shown an interesting enhancement of accuracy by taking into account the GNSS data in a multisensory system composed of dead reckoning sensors, vision based position and a 3D map. The estimator works under a tightly coupled scheme (Peyret 11).

The results presented hereafter use real GPS data, recorded in the city of Belfort, France with an uBlox receiver implemented in a Safedrive receiver, without any additional sensor. We use the raw pseudorange measurements in a classical Extended Kalman Filter (EKF) in order to compare 2D positioning results when we use all the received satellites or when we only use the LOS signals. Figure 5 draws the global trajectory of the vehicle. The red line is used as a reference (the ground truth): it is the result of measurements performed with a RTK receiver and a post processing step. The blue circles and the green stairs are respectively obtained with all the received satellites and with only the LOS satellites. Figure 6 shows three zooms of interesting areas where multipath are clearly visible on the blue path. The NLOS satellites exclusion does not solve all the errors but enhances clearly the results. The first example shows a stop of the vehicle, the second one illustrates a roundabout. The third one is obtained in an urban canyon.

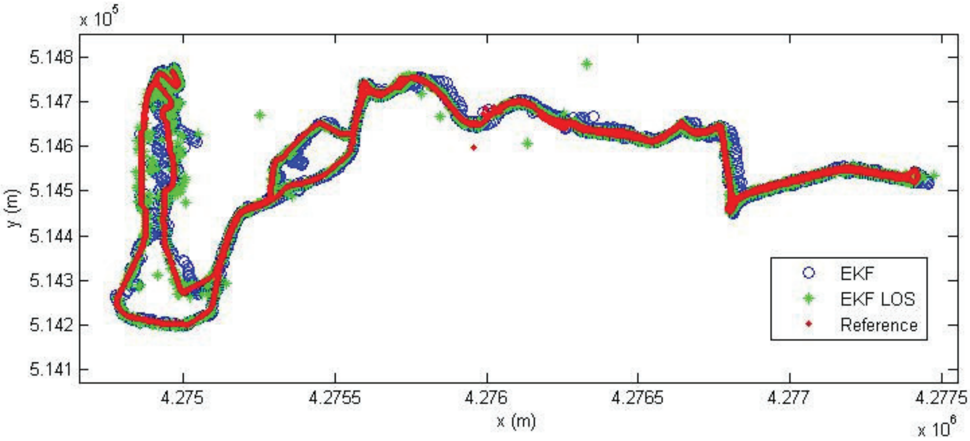

Fig. 5. View of the vehicle's trajectory in Belfort. The position is calculated with a classical EKF, using all the available satellites (blue circles) or only the LOS ones (green stairs). The results are compared to the ground truth measured with a RTK receiver (red points).

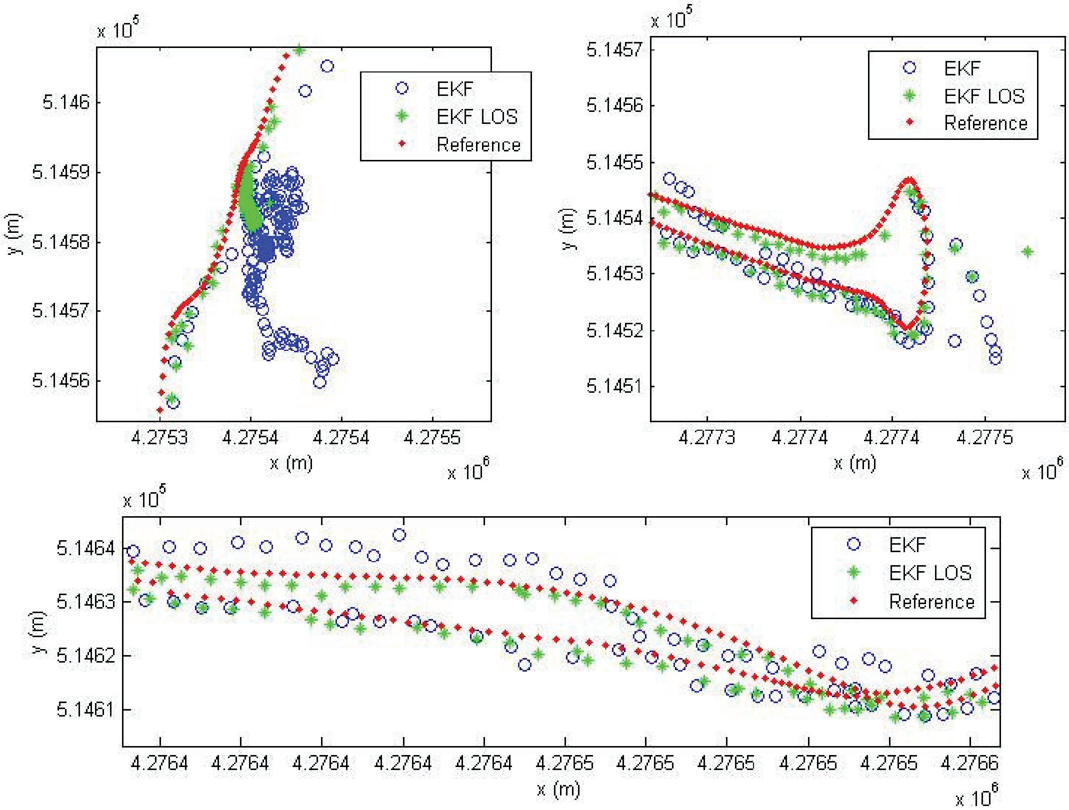

Fig. 6. Effects of the NLOS signals exclusion in presence of strong multipath.

The results presented here are a first step of the use of the images. A quantitative analysis of these results is not possible with this data set because of the non synchronization of the measurements.

The figures presented have shown the efficiency of the exclusion method when a sufficient number of satellites can be received. However, in more constricted environments, this will create unavailability. Thus, for the remainder of the project, we will model or evaluate deterministically the pseudorange errors created by the obstacles in order to effectively use these NLOS received signals.

4. Conclusions

In this paper, we have presented the CAPLOC project objectives and principles. The project begins its second year (and is planed for three years). The goal of such a project is to show the feasibility of an intelligent use of the satellites in a constricted environment in order to provide a solution able to answer the accuracy requirements of land transportation systems, road, railway or tramway.

The first results obtained on image processing techniques have been presented. The proposed method is based on geodesic reconstruction by dilatation (with an optimal contrast parameter) coupled with an adapted clustering algorithm. This method respects the real time constraint and provides satisfying results (96.09 % of good detection).

We have shown how the knowledge of the satellite states of reception given by the images can enhance localisation accuracy by excluding the disturbing satellites.

In image processing, future works concern the classification of interest objects into three classes (sky, vegetation and building). It will permit to quantify the influence of the environment (vegetation, building, etc) on signals propagation.

Acknowledgements

This work has been supported by the PREDIT (program of research, experimentation and innovation in land transport) and is funded by the French ministry MEDDTL.

References

Attia, A., Meurie, C., Ruichek, Y., Marais, J. (2011), Counting of satellites with direct GNSS signals using Fisheye camera. A comparison of clustering algorithms, IEEE International Conference on Intelligent Transportation Systems (ITSC), Washington, USA, October 2011.

Cohen, A., Meurie, C., Ruichek, Y., Marais, J. (2010), Characterization of the reception environment of gnss signals using a texture and color based adaptive segmentation technique, IEEE Intelligent Vehicles Symposium (IV), pp. 275–280, San Diego, California, June 2010.

Godefroy, B., Sayerse, P. (2006), Amélioration du positionnement par satellites dans un environnement fortement urbanisé, grâce à la prédiction de la propagation des signaux GNSS, Revue Navigation, Vol. 54, n° 213, jan. 2006, pp. 17-35.

Kovář, P., Vejražka, F., Seidl, L., Puričer, P., (2005), Assessment of the EGNOS Signal Availability for Land Mobile User. 12th Saint Petersburg International Conference on Integrated Navigation Systems. Saint Petersburgh 2005, May 2005, pp. 148-156.

Lentmaier, M., Krach, B., Robertson, P. (2008), Bayesian Time Delay Estimation of GNSS Signals in Dynamic Multipath Environments, *Hindawi Publishing Corporation, International Journal of Navigation and Observation,* Vol. 2008, Article ID 372651, 11 pages.

Marais, J., Ambellouis, S., Flancquart, A., Berbineau, M. (2008), Dispositif de localisation. French patent: WO/2008/040896, International patent: 10 avril 2008.

Marais, J., Berbineau, M., Heddebaut, M. (2005), Land Mobile GNSS, Availability and Multipath Evaluation Tool, *IEEE Trans. On Vehicular Technology*, Sept. 05, Vol. 54, Issue 5, pp. 1697-1704.

Meguro, J.-I., Murata, T., Takiguchi, J.-I., Amano, Y., Hashizume, T. (2009) GPS multipath mitigation for urban area using omnidirectional infrared camera, *IEEE Trans. On Intelligent Transportation Systems,* vol. 10, no. 1, pp. 22–30, Mar. 2009.

Meurie, C., Ruichek, Y., Cohen, A., Marais, J. (2010), An hybrid an adaptive segmentation method using color and textural information, IS&T/SPIE Electronic Imaging 2010 - Image Processing: Machine Vision Applications III, Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol. 7538, 11 pages, California USA, January 2010.

Pervan, B.S., Lawrence, D.G., Cohen, C.E., Parkinson, B.W. (1996), Parity space methods for autonomous fault detection and exclusion using GPS carrier phase, *Position Location and Navigation Symposium*, 1996, IEEE 1996 Volume , Issue, April 1996, pp. 649–656.

Peyret, F., Bétaille, D., Mougel, F. (2011), Non-Line-Of-Sight GNSS signal detection using an on-board 3D model of buildings, Proc. of the 11th international conference on ITS Telecommunications (ITST), August 2011, St Petersburg.

Suh, Y., Shibasaki, R., (2007), Evaluation of satellite-based navigation services in complex urban environments using a three-dimensional GIS, IEICE Trans. Commun. Vol. E90-B, n°7 - July 2007.

Wang, J.-H., Gao, Y. (2007), High-Sensitivity GPS Data Classification Based on Signal Degradation Conditions, *IEEE Transactions on Vehicular Technology*, Volume 56, Issue 2, March 2007, pp. 566–574.